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NONPOINT SOURCE CONTROL GUIDANCE

SILVICULTURE

MARCH 1977

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16 ABSTRACT

This document is a vehicle to interface and guide effective public and professional effort via a ten-step process that forms and structures the participation and inquiry necessary to develop Best Management Practices (BMP) for forest harvesting operations. Thus BMP can be developed that reflect land capabilities and local conditions. Application of the process leads to: (1) identification of complementary elements of Federal and State agency programs; (2) identification and assessment of present and future nonpoint problems; (3) the analysis of identified problems; (4) the definition of BMP design criteria based on simultaneous occurrence of critical problem creating conditions; (5) the design and implementation of technically sound, economically feasible, socially acceptable and institutionally possible local BMP for forestry's contribution to a water quality management system. Information needs are identified; prevention and reduction BMP are presented for defined conditions. The document is based on legislated requirements and within a concept of environmental planning.

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SUBJECT: Transmittal of Document Entitled "Nonpoint Source Control Guidance, Silviculture"

FROM : E. M. Nottingham, Acting Director
Water Planning Division

TO : All Regional Water Division Directors
ATTN: All 208 Coordinators
All Nonpoint Source Coordinators

TECHNICAL GUIDANCE MEMORANDUM: TECH 37

Purpose

Attached is a recently prepared nonpoint source control document that identifies, defines, and structures the form and sequence of the water quality management process in relation to silviculture. It presents a methodology for the water quality management planner and persons knowledgeable in silvicultural practices at the State and local level to work closely and in a complementary manner for the development of silvicultural Best Management Practices (BMP).

Guidance

The document is part of a series. Additional issues include construction, mining, agriculture, and hydrologic modification. The series is designed to provide State and 208 areawide agencies, Federal agencies and various publics with information to assist them in carrying out their water quality planning and implementation responsibilities.

These documents are provided in accordance with policies and procedures of 40 CFR, Part 131 -- "EPA will prepare guidelines concerning the development of water quality management plans to assist State and areawide planning agencies in carrying out the provisions of these regulations."

This silviculture document is not designed to present the answers -- "the BMP" -- for application on a given tract of land. The diversity of our forested land is much too broad for such an approach. The document is designed to present an approach for carrying out the BMP concept as it relates to silvicultural activities. This approach may then be refined and added to with local knowledge by local people.

The described method inquires into the technical aspects of identifying and assessing existing and future silvicultural nonpoint source problems, analyzing the problems, and developing procedures needed for designing localized BMP. This method recognizes the need for flexibility in water quality management agencies. Following this, descriptions and examples of BMP are presented for the defined conditions.

(cont)

NONPOINT SOURCE CONTROL GUIDANCE
FOR
SILVICULTURE

by

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We appreciate the cooperation of the many people in various professional fields within the U. S. Environmental Protection Agency (EPA) and other Federal government agencies, environmental organizations, universities, the forest industry, and private forest consulting work in providing constructive observations and much of the information used in preparing this document.

All photographs courtesy of U. S. Forest Service.

PREFACE

Section 208 of Public Law 92-500 requires that water quality management planning include a process that identifies nonpoint sources of pollution, including those associated with silviculture and related runoff, and establishes procedures and methods to control these sources, to the extent feasible in a given locale. This document is EPA guidance on Best Management Practices for Silviculture developed pursuant to Section 208.

For purposes of this guidance, silviculture is defined as that part of forest management which deals with the husbandry of forest crops. The term includes all activities related to this purpose from the preparation of an area for restoration of forest vegetation, through the establishment, culture and protection of the growing crop, to that crop's harvest and transport from the production area.

Every State has areas where silvicultural activities such as tree planting, tree cutting, tree stand improvement or similar cultural practices take place. Commercial timberlands on which silviculture may be a major activity comprise a significant part of the forest land of the Nation, except in the Great Plains region, parts of Alaska, and some of the Southwest. Twenty-seven percent of the commercial timberlands are publicly owned. Seventy-three percent are privately owned -- of these 59 percent are in small private holdings and farm woodlots and 14 percent are held by private industry.

Significant differences in timberland ownership patterns and forestry programs in various parts of the Nation will influence not only the water quality program but also the regulatory, institutional, and public participation

arrangements. For example, in the East only one-fourth of the commercial timberlands are Federally owned, with the remainder being in small private timber holdings, farm woodlots, and industrial timberlands. In the Northwest a major portion of the commercial timberlands are Federally owned.

This guidance will identify, define, and structure the form and sequence of the water quality management planning process in relation to silviculture. It may be used to:

1. Guide development of more focused, refined and detailed procedures by local experts -- procedures that reflect local practicality, site-specific information, and implementation of the Best Management Practices (BMP) concept;
2. Guide the identification and application of relevant, technical forestry knowledge of nonpoint source pollution control practices appropriate to solve local water quality problems caused by silvicultural activities; and
3. Guide the design of program management to attain optimum silvicultural contribution to the water quality management program.

While this guidance does not specifically address aspects of forest management other than silviculture, it does establish a process that can be applied in controlling other nonpoint source water pollution problems associated with forest recreation use and with activities involving the deliberate modification or change in vegetative cover. These may include changes made to meet other forest land management objectives, such as wildlife habitat improvement, water yield improvement, and fire hazard reduction.

Interactions are extremely complex between the many variables which affect both the natural pollutant loads of streams and water bodies and the

degree to which silvicultural activities modify these loads. Therefore, the interactions among the physiographic, biologic, and climatic characteristics that created the inherent water pollution hazard of an area are carefully examined and related to the characteristics and sensitivity of receiving waters. Existing or potential impacts of silvicultural activities and practices on water quality are analyzed in the context of these interactions.

Using this procedure, very complex problems can be systematically reduced to a series of interrelated, but relatively simple, problems that can be resolved with technical knowledge. A first step towards BMP development is the definition of BMP design criteria. This is followed by identification of alternative, technical solutions to meet these criteria by persons knowledgeable on silvicultural operations and their relation to water quality.

Following these steps, the technically practical silvicultural BMP can be made consistent with legal, institutional, economic and social considerations to yield an implementable BMP. The purpose of the silvicultural BMP is to prevent and/or reduce the pollution of waters from silvicultural activities.

The silvicultural BMP, together with BMP of other nonpoint categories which contribute to the water pollution problem in the drainage area, can be analyzed to determine their respective contribution to the protection and propagation of fish, shellfish and wildlife, and in providing for water-oriented recreation. The BMP that achieves national goals and supports program emphasis required to meet other local water quality goals can then be identified for each category.

Implementation schedules of selected BMP for each category must be established. The manpower, funding, technical knowledge, and legal basis

needed to obtain the first round of pollution control should be identified. Then, the institutional mechanisms and the responsibility for implementation of a successful water quality management program can be defined and scheduled. At that time, the machinery will be in place for successful definition of information needed to monitor and enforce silvicultural BMP.

The methodology presented in this guidance is structured to allow different levels and intensities of planning and implementation. It concentrates on leading the planner to identify actual problem areas and on procedures to help the planner establish an appropriate technical framework for effective, practical corrective action. It fosters the interchange of ideas and information between the water quality management planner and professionals in the field of forestry, forest hydrology, aquatic biology, and allied disciplines.

The expertise for application of available technology is presently centered in Federal and State forestry agencies, in the more progressive companies within the forest industry, in the academic community, and in a few consultant firms. EPA has been using this expertise in developing both program and technical guidance and in promoting technical assistance to and through the State forestry organizations.

TABLE OF CONTENTS

	Chapter and Page
PROGRAM INFORMATION NEEDS AND CHECKLIST	I-1
Program Information Needs	I-2
Program Checklist	I-3
SILVICULTURE IN RELATION TO WATER QUALITY MANAGEMENT	II-1
Description of Activities	II-4
Disturbances Associated with Silvicultural Activities	II-6
Soil and Vegetation Disturbance	II-7
Natural Drainageway and Stream Channel Disturbance	II-10
Potential Pollutants from Activities	II-11
Best Management Practices	II-12
ASSESSMENT, ANALYSIS, AND BMP DESIGN FOR SILVICULTURAL PRACTICES	III-1
Assessment	III-4
Determination of Inherent Pollution Hazards	III-4
Interpretation and Analysis	III-7
Interactions	III-9
Activity Identification and Evaluation	III-11
Establishing Appropriate BMP Design Criteria	III-12
POLLUTION CONTROL PRACTICES	IV-1
Prevention Practices	IV-3
Reduction Practices	IV-11
Considerations for Specific Land Areas	IV-27

LIST OF FIGURES

	Chapter and page
1 - NONPOINT POLLUTION CONTROL PROCESS FOR SILVICULTURE	III-1
2 - IMPROPER DATA INTERPRETATION	III-6
3 - EXTREMELY HIGH INHERENT POLLUTION HAZARD	III-10
4 - TRACTOR HARVESTING OPERATION	IV-6
5 - CABLE HARVESTING OPERATION	IV-7
6 - PREPLANNED STREAMSIDE MANAGEMENT AREA	IV-8
7 - WELL LOCATED MAIN ROAD	IV-8
8 - ROAD CROSSING A MEADOW	IV-9
9 - LOW USE ROAD	IV-9
10- TRACTOR ROAD	IV-10
11- MULCH ON ROAD FILL	IV-15
12- LOG BRIDGE	IV-16
13- ABANDONED LOGGING ROAD	IV-16
14- LOG-HAUL ROAD	IV-17

LIST OF TABLES

	Chapter and Page
I - FRAMEWORK FOR PREVENTION AND REDUCTION WATER POLLUTION CONTROL PRACTICES	IV-2
2 - PRINCIPAL TYPES OF REDUCTION PRACTICES FOR EROSION CONTROL APPLICABLE TO SILVICULTURAL ACTIVITIES	IV-43
3 PRINCIPAL TYPES OF PESTICIDES PRACTICES APPLICABLE TO SILVICULTURAL ACTIVITIES	IV-88

CHAPTER I

PROGRAM INFORMATION NEEDS, AND CHECKLIST

Program Information Needs

During the planning process, the nonpoint source categories (i.e., silviculture, agriculture, construction, etc.) which contribute to the pollution problem, as well as the extent to which they contribute, should be identified. Appropriate BMP for the situation should be selected and decisions should be made as to how and where these BMP can most effectively be scheduled and implemented to resolve each respective problem.

The types of information needs which relate to technical considerations are:

1. Identification and assessment of existing and potential silvicultural pollution problems
   - Location of planned, ongoing and completed silvicultural operations which could or are creating pollution problems in forested and associated watered areas
   - Location and type of silvicultural activities within watersheds above the polluted stream or stream segments
   - Silvicultural practices and methods of operation that could be or are contributors to the pollution problem in streams or other water areas
   - Site factors, such as steepness of slope and erodibility soils, associated with these problems and sources
   - Areas and types of ownership on which the practices and methods of operation take place
   - Variations, if any, in pollution problems associated with the weather extremes or seasonal scheduling in which the practices and methods of operation take place

- Variations, if any, in pollution problems in relation to the proximity of activities to receiving waters
- Sensitivity of the receiving waters and their associated aquatic environment to changes in pollution loads

5. Identification of feasible means to control pollution
   - Alternative practices which are applicable to the activity and to the situation in which it occurs, and which promote harmony between BMP for pollution control and for other appropriate uses of the land
   - Optimum mix of feasible prevention and reduction or mitigation practices and operative methods needed to achieve cost-effective pollution control
   - Appropriate scheduling for BMP implementation
6. Identification and participation of public groups in BMP development and implementation
   - Interested general public
   - Professional societies, and associations
   - Forest industry and timber and woods operators
   - Other agencies engaged in water quality management planning
   - Federal agencies
   - State forestry agencies
   - State water quality agencies
   - Teaching and/or research institutions
   - Appropriate local governmental units
   - Professionals of related specialties

The information needs for elements dealing with arrangements required for effective program implementation will be more clearly defined in other documents. However, that information might logically include:

- Adequacy of present programs in preventing pollution from silvicultural operations
- Program modifications needed to prevent pollution problems from arising and maintain production of forest benefits
- Criteria for utilizing manpower and programs across agency lines.

Program Checklist

Much of the data needed for water quality management planning already exist but are scattered through various Federal, State, and local agencies; professional organizations; research institutions; and private enterprise. These data must be brought together, interpreted in the proper context, and synthesized into a system. Following is a checklist to aid in proper selection, interpretation, and synthesis of these data. This checklist may be refined at the local level, if necessary.

1. Identification and assessment of pollution problems

   Does the planning process include:

   - Use of all logical sources of information? For example, have federal agencies such as the Forest Service and Bureau of Land Management; the State Forestry agencies; the forest industry; the academic community; private land-owners; State fish and wildlife agencies; and others been contacted and given an adequate opportunity to provide their own input into this effort?

-- Use of a screening process that identifies forest land in terms of location, extent, types and spatial distribution?

-- Use of a screening process that identifies and defines existing or potential pollutant sources on forest land with particular attention to the relationship of these pollutant sources to a water quality segment? This includes the identification and definition of associated types of forest uses, conditions in the area which are hazardous to water quality if care is not taken in silvicultural operations, any polluted conditions in waters in the area in which these uses occur, and the related site conditions which may be contributing to these pollution conditions? Is the information being interpreted and used at the appropriate degree of detail for problem assessment and analysis and BMP design?

-- Use of a technique that allows separation of man-caused sources of pollution from natural causes?

-- Use of an analytical method that recognizes and adequately considers different time frames and operational methods associated with the various silvicultural activities?

-- Consider and include procedures that reflect the complexity of geomorphic processes, natural ecosystems, and wildland hydrology?

3. <u>Identification of feasible means to control pollution</u>

Does the planning process

-- Include both pollution prevention and pollution reduction viewpoints in BMP design?

-- Look past the first use of the land, e.g., look at superimposed or subsequent uses that may occur at the same site?

-- Identify and define the land ownership range by type and size?

-- Identify and define the economic feasibility of a specific practice, a range of practices?

-- Use professional forestry expertise in designing BMP's for each kind of inherent hazard to water quality in relation to existing and anticipated forest uses?

-- Consider, in BMP design and location: the variations in land capability; the size and shape of the area on which the activity takes place; the type, timing, and intensity of the activity; the owner characteristics and objectives; and the silvical characteristics and regeneration requirements?

-- Utilize information on location of sensitive areas, access location, anticipated harvest sites, and past abused areas in developing BMP design criteria?

-- Allow for increased water quality improvement (while maintaining production) as experience is gained and new knowledge is applied through refinement of BMP's?

-- Allow for sufficient flexibility for professional forestry judgement in BMP design and implementation?

8. <u>Identification and participation of public groups in BMP development and implementation</u>

Does the planning process

-- Recognize and establish procedures for continued active participation of the forestry community?

- Coordinate silviculture with other nonpoint pollution control priorities and with other land, air, and water programs?
- Utilize local mechanisms for public participation and public education?

While this document is not intended as a guide to the development of appropriate implementation arrangements, the planning process might logically include:

- An analysis of existing institutional capabilities of Federal, State, or local agencies as they may apply to control pollution generated by man's activities on forested land
- Identification and definition of a system to implement BMP's, as quickly and completely as possible, under a combination of existing regulatory, nonregulatory, and institutional arrangements
- A strategy for incorporating state-of-the-art advances in knowledge, to the extent feasible, into institutional arrangements and more effective BMP mixes
- Identification of governmental and private sector programs and institutional arrangements that can address the defined pollution problem
- Identification of a specific target date for creation of an effective program package to solve the pollution problem.

CHAPTER II

SILVICULTURE IN RELATION TO WATER QUALITY MANAGEMENT

Silvicultural activities, potential pollutants, and practices to prevent and reduce pollution are interrelated. This chapter presents and briefly discusses the types of activities, the types of potential pollutants, and the types of water pollution control practices (BMP) in silviculture. The interrelationship and flexibility between these three factors allow forest managers to successfully integrate water quality goals with their other management objectives, and therefore contribute substantially to a water quality management system on the landscape.

Although most silvicultural activities affect only a portion of a general forest area at any given time, they are usually a part of a cyclical process designed to yield a continuous supply of wood fiber and wood products. Certain activities, such as those associated with establishment and removal of the crop, occur only once during the crop cycle. Depending on the tree species and the area of the country, a crop cycle may span 10 to 100 years or more. However, the impact of certain silvicultural activities on the pollution potential may be heavy during operations and may linger until the forest has sufficiently regenerated to restore the water-handling capability of the area to pre-activity levels. Other activities, such as those associated with protection from fire, disease, and insect, and those associated with crop improvement, may occur several times within the crop cycle. Thus, the span of silvicultural activities can increase both the short-term and long-term pollution potential.

Description of Activities

While all silvicultural activities are interrelated, activities producing pollutants are associated with (1) access and transport systems (log roads,

etc.), (3) harvesting, (4) crop regeneration, and (5) intermediate practices and activities (thinning or fire, insect, and disease control). The amount and type of pollutants generated by these activities are strongly influenced by the magnitude and characteristics of climatic events, the physical characteristics of the area (soils, topography, etc.), and the characteristics of the individual operations as they are practiced in a specific area.

The four classes of activities associated with silviculture which may produce pollutants are:

1. Access Systems

Access to, from, and within forested areas for the purpose of carrying out silvicultural activities usually is provided through a combination of resource management roads and trails. In some areas, waterways, airstrips, and railroads may also be important. The roads, which generally make up a part of a broader interconnected transportation system serving many forest user, including recreation and forest protection, range from very narrow trails through unsurfaced roads to high-speed paved roads. How often these access systems are used for silvicultural purposes varies from intensive to only occasional use over a number of years.

The forest access-road system is often a major contributor of sediment to the streams in forested areas. These sediment loads may originate as a result of road construction (including stream crossings), associated mass soil movement due to slides and slips when built on unstable terrain, direct erosion from the roads, and indirect erosion caused by changes in drainage patterns and systems. In addition to sedimentation problems, other pollution problems may be created due to debris

(organic pollution) resulting from construction and log transport, and from herbicides used to control the growth of undesirable vegetation on the right-of-way.

9. Harvesting

Harvesting includes the process of felling the tree, preparing it by limbing, cutting it into desired lengths, and moving it to a central, accessible location for transport out of the forested area. The useable material is moved (skidded or yarded) to a temporary storage site or "landing" by one of three basic methods: animal or tractor (on skid trails), groundlead or highlead cable, or various skyline cable methods. Balloons and helicopters are also being used to a limited extent in some areas. The animal or tractor and the groundlead or highlead cable methods usually involve the dragging of at least a part of the material over the ground surface, whereas the skyline cable, balloon, and helicopter methods generally lift the material clear of the ground.

The harvesting of wood materials results in partial to complete removal of forest cover and may compact the soil and remove, add to, or redistribute the protective cover on the soil surface. Thus, harvesting methods may affect the erosion process and consequently, the potential for sediment pollution. In addition to sediment production, harvesting can create an accumulation of organic debris and slash which may be washed from the forest floor or otherwise reach the stream, especially when intense harvest operations are carried out in close proximity to the water area. Harvesting can also result in thermal pollution due to removal of the canopy over streams.

There are three basic systems of harvesting used in the United States. These are single tree (selection), partial removal, and clearcutting. Each of these systems results in a different type and degree of pollution-generating potential because of the differences in associated site disturbance. The single tree, or selection system, involves annual or periodic removal of certain trees either singly or in small groups. It is generally adapted to those species that will reproduce satisfactorily under severe competition for soil moisture, soil nutrients, and light.

Partial removal is normally seed-tree or shelterwood cutting to create small openings which are seeded naturally and protected by surrounding trees. In the shelterwood system, the old crop is removed in a series of partial cuttings, each of which is spaced and timed to provide a natural source of seed, shade, and shelter for the new crop. The seed-tree cutting system involves the removal, in one cut, of the mature timber from an area, except for those trees left as a seed source for natural regeneration.

Clearcutting is a silvicultural system in which the old crop is cleared over a considerable area at one time. Reproduction is secured either artificially by seeding or planting, or naturally by seed distributed from trees standing outside the area cleared or from trees felled in the cutting operation.

3. Crop Regeneration

Crop regeneration refers to the re-establishment of a forest cover on areas from which trees have been removed by some past occurrence, such as wildfire, timber harvesting, or temporary conversion to some use other than the growing of trees. When trees have been absent from the site for a number of years, regeneration must generally be achieved

through seeding and planting. Regeneration of a harvested area includes both the natural regenerative process and man's activities in preparing the site and subsequent planting or seeding. The method of regeneration is determined largely by environmental and silvical requirements of the tree species involved, limitations imposed by characteristics of the land, economic considerations, and the land manager's desire for forest composition. In some plant communities, natural regeneration under any of the harvesting systems may also occur by regrowth from roots or stumps.

Preparation, as well as protection, of an area is sometimes needed for regrowth of a stand. Where site preparation for regrowth is needed, the major activities may include:

- Debris removal to reduce fire hazard and allow use of equipment for subsequent operations;
- Reduction or removal of brush or shrub cover and undesirable species of trees; and
- Cultivation of the soils.

When used indiscriminately for site preparation, fire, chemicals, and soil-disturbing machinery increase the potential for sediment and other pollution to occur. The timespan for such pollution to occur is variable depending upon the climatic factors, the soil productivity and its influence on rate of plant growth, the species of vegetation planted or seeded, and the operational schedule. In some areas the timespan may be a single growing season, while in other areas it may cover several years.

4. Intermediate Practices

Other silvicultural practices relating to thinning of an immature forest, fertiliser application, and pesticide treatments may be undertaken

during the crop cycle. The thinning process involves the removal of selected trees from an immature forest. In essence, this is a type of harvesting which would tend to create potential sediment-generating conditions if carelessly carried out. Chemical application of fertilizers and pesticides during intermediate practices can result in water pollution, if improperly carried out or adversely affected by an extreme and unexpected natural event.

Disturbances Associated with Silvicultural Activities

Nonchemical forms of pollution that result from silvicultural activities generally relate to disturbances of the soil and vegetation. The kind and amount of disturbance is largely dependent on five main factors:

1. Characteristics of the area on which the silvicultural activities are carried out, i.e., nature of the soils, vegetation, climate, and topography;
2. The type and character of the activity, e.g., the specific regeneration system used in carrying out timber harvesting -- selection, shelterwood, seed-tree, or clearcutting;
3. The method used in carrying out the activity, e.g., for timber harvesting -- animal, tractor, high-lead cable, skyline cable, balloon, or helicopter;
4. The specific features of the activity, e.g., intensity, and size and shape of the area on which it is applied; and
5. The location of the activity, i.e., its proximity to stream channels and lake shores.

Timing of the activity is a sixth factor which may be important in some situations. Where applicable and feasible, the amount of soil disturbance

may be reduced by logging when the ground is frozen; when it is covered with snow; or when the ground's soil moisture is relatively low.

Although generalities can be misleading and must be carefully examined by appropriate professionals for application to local situations, these generalities are useful in establishing a common framework for examining alternative solutions to water pollution problems. To illustrate, the relative impacts of the different categories of harvesting systems based on the disturbances which can create water pollution problems are generalized in the following discussion.

Soil and Vegetation Disturbance

It may be necessary to construct additional roads and trails where an access system is inadequate to serve the particular harvesting system. This construction activity can result in severe to complete disturbance of soil and vegetation. The extent of such disturbance can be minimized by fitting the access routes to the terrain, by minimizing stream crossings, by using appropriate design criteria, and by using the least soil-disturbing and soil-impacting equipment and techniques.

1. Selection Cutting Systems

Due to the scattered nature of cutting, the selection systems are generally not adapted to use of high-lead, skyline, balloon, or helicopter logging methods. Thus, they usually require an extensive system of roads and skid trails. Disturbances of the general forest area are usually limited to soil and undergrowth in the area immediately around the individual trees or groups of trees harvested, with little deterioration of the soil-holding network of plant roots. Since selection cutting generally involves the removal

of only the mature, over-mature, or dead trees; maintenance of a healthy stand of trees often requires more frequent entry to the harvest area than other regeneration methods. Further disturbance of the soil, although relatively small, can occur at fairly short re-entry intervals.

3. Shelterwood Cutting Systems

Several ways in which the shelterwood systems may be applied include general progressive cutting of trees over the entire harvest area, and cutting in strips or in groups. Tractor logging is generally adapted to the system, but where strip or group shelterwood modifications are used, and wood volumes and terrain are favorable, other logging methods, such as high-lead cable or skyline cable, may be employed. An extensive system of roads and skid trails is generally needed where tractor logging is used. Fewer, more widely spaced roads, may be adequate with the cable systems.

Since the most important function of the series of partial cutting is to create ideal site conditions for the germination of natural seed fall, a certain degree of disturbance to soil and ground cover throughout the cut area is necessary. Where initial cutting fails to create the proper seedbed conditions, artificial methods to prepare small seed spots at close intervals are often used. A minimum of two cuttings is required in the simplest application of shelterwood cutting. Under intensive management, more than ten cuttings often are made in the gradual process of simultaneously freeing the reproduction and removing the mature stand. Often the regeneration period ranges from 10 to 20 years, but may extend to 60 years. Therefore, some degree of redisturbance to soil and vegetation can occur at rather frequent intervals.

3. Seed-tree Systems

In some classifications, the seed-tree system has been included under clearcutting systems, since the area is clearcut except for certain seed trees which ordinarily make up less than 10 percent of the total volume of wood on the area. Like clearcutting, any one or a combination of the logging methods may be appropriate, depending upon site conditions, economics, volume of timber, and many other factors, including proximity of the activity to the receiving waters. In comparison to selection cutting, fewer roads and skid trails are needed in seed-tree systems. Severe disturbance of soil and vegetation may occur over most of the cut-over area, unless skyline, balloon, or helicopter methods are used. The amount and degree of disturbance are usually less with high-lead systems which raise at least a part of the log off the ground than with tractor logging where all of the material is dragged over the ground. After the new crop is established, the seed trees usually are removed in a second cutting. Some redisturbance of soil and vegetation occurs as these trees are harvested. Both the seed-tree and clearcutting systems can result in at least a temporary deterioration of the soil-holding network of tree roots over a relatively large area. This can be a particularly important consideration in steep terrain and in areas immediately adjacent to stream channels.

4. Clearcutting Systems

The disturbance of soil and vegetation by clearcutting systems is similar to that of seed-tree systems. The most important difference is that all material is cut so that the area is laid bare of trees. In many of the larger clearcut areas, reforestation involves site preparation for

artificial reproduction. This involves removing much of the remaining ground cover and adding further to the disturbance of soil and vegetation. On those clearcuts where logging is done by methods which lift the harvested material clear of the ground, and where revegetation occurs naturally without further site preparation, the overall amount of soil and vegetation disturbance between crop removal operations can be less than with systems that require more frequent entry. Redisturbance does not occur until the reproduction is ready for thinning.

Natural Drainageway and Stream Channel Disturbance

1. Selection Cutting -

Except for disturbances associated with roads and other means of access, natural drainageways and stream channels are normally not affected by selection cutting unless the logs are dragged across the drainageway or channel, or unless limbs and other unmerchantable portions of the tree are allowed to accumulate in the channels.

2. Shelterwood Cutting

The degree of disturbance to natural drainageways by shelterwood cutting depends on how the system is applied. Where the system involves general progressive cutting, the impact is similar to that of selection cutting. Strip or group shelterwood cutting methods, which involve concentrated cutting in small areas, may also result in disturbance by logging equipment of minor tributary drainageways.

3. Seed-tree cutting

In addition to disturbances associated with road and trail crossings, disturbance of natural drainageways and stream channels may occur whenever

logs are dragged across the land surface. Such disturbance is minimal where skyline, balloon, or helicopter methods are used. In seed-tree cutting the danger of woody debris entering drainageways and stream channels within the cut area is relatively high.

4. Clearcutting

Disturbances of natural drainageways and stream channels are similar to those associated with seed-tree cutting. As with the seed-tree system, the degree of disturbance is inversely proportionate to the amount of material that is dragged across or through the drainageways and channels.

Potential Pollutants From Activities

The most important pollutants which may be generated by silvicultural activities are sediments and debris, chemicals, including those in the form of nutrients and pesticides; and thermal effects. The origin of the pollutants is generally related to more than one of the activities of the total silvicultural operation.

1. Sediment

An increase in sediment is the most common form of pollution resulting from silvicultural activities. The additional sediments usually result from the accelerated erosion of soils, but may also result from debris and other organic and inorganic waste. Excessive amounts of sediment affect stream ecology by smothering bottom organisms through the formation of bottom blankets. They carry nutrients and pesticides, clog streams and downstream reservoirs, inhibit reproduction of many important fish species, and alter stream flow and speed. Suspended sediments interfere with the photosynthesis process by reducing light penetration.

3. Nutrients

Nutrient loss, above the natural level, may occur where fertilizers are carelessly applied during the course of silvicultural operations. Soluble nutrients may reach surface or ground water through runoff, seepage, and/or percolation. Insoluble forms may be absorbed on soil particles and reach surface water through erosion processes. Nutrients may also reach surface water by direct washoff of slash, debris, and recently applied fertilizer. Excessive nutrients can lead to imbalance in the natural life cycles of water bodies.

3. Pesticides

Pesticides, when applied during forest management activities, may be insoluble or soluble. Pesticides entering surface or ground waters follow approximately the same pattern as nutrients. Pesticides, carelessly applied, may result in acute toxicity problems in the water bodies or insidious toxicity problems throughout the entire food chain, from the lowest to the highest forms of life.

4. Organic Pollutants

Debris, i.e., slash and other nonmerchantable materials generated by silvicultural activities, may result in organic pollution if an inordinate amount is placed or washed into streams. This organic material may reach surface waters through direct dumping, washoff, and leachate from log storage. The organic material places an oxygen demand on the receiving waters during decomposition. In addition, these materials may lead to other problems such as changes in tastes, odors, colors, and excessive nutrients.

5. Thermal Pollutants

Thermal pollution may result from silvicultural activities where the removal of the canopy cover from stream bodies causes the water temperature to rise. Temperature is a significant aspect of water quality. In some cases, it may strongly influence dissolved oxygen concentrations and bacteria populations in streams. The saturated dissolved oxygen concentrations in streams is inversely related to temperature.

Best Management Practices

"The term 'Best Management Practices (BMP)' means a practice, or combination of practices, that is determined by a State (or designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals"1/

Among the various technical aspects to be considered in BMP design and selection are:

1. The variability of characteristics on individual source areas in terms of topography, soils, geology, etc., and their effect on natural pollution hazards of the area;
2. The variability in climatic factors which influence both the detachment and transport processes;
3. The variability in the recovery time of the site as it is influenced by factors, such as climate, soil productivity and plant species; and
4. The variability in the transport behavior of different pollutants and in the reactions of the receiving waters to these pollutants.

1/ [Ref 40 CFR, 130.3(q)].

In most cases, this variability will prevent a single BMP from covering all activities and situations. BMP must be structured with these variations clearly in mind and with full consideration of the particular water quality problem to be solved. Further considerations include the practicality of securing early implementation of appropriate Best Management Practices, the social and economic costs of implementation, and the benefits (water quality or otherwise) to society that will result.

The control measure must be fully integrated into the total management system for the particular forest area and be feasible not only from a technical standpoint but also from the financial, legal, and institutional standpoint. To the extent feasible, soils, nutrients, pesticides, and other chemicals must be kept on the land area where they perform their intended function of assisting tree growth and health.

Best Management Practices which can be applied to a silvicultural operation to prevent or reduce pollution of surface and/or ground waters can be classified as two general types. These are (1) prevention measures as part of planning, policy and management, and (2) reduction measures applied on the land as an integral part of the silvicultural activity. Reduction and prevention measures are generally described in "Processes, Procedures and Methods to Control Pollution Resulting from Silvicultural Activities", EPA 430/9-73-010. More specific information on logging roads for the Pacific Northwest is contained in "Logging Roads and Protection of Water Quality", EPA 910/9-75-008, Region X, Environmental Protection Agency.

1. Prevention

Prevention through management decision involves the incorporation of water quality protection in organizational policy and in the planning, design,

and scheduling of silvicultural activities. At this stage, location and design of logging access roads, intermediate activities, harvesting methods, and reforestation decisions must be made to prevent or minimize the aggravation of inherent pollution hazards, for example:

a. Pollution potentials associated with access systems may be greatly decreased by careful location, design, construction and maintenance of the roads. Waterways should not be used as roadways or skid trails. Except in lowlands or swampy areas where their use is unavoidable, wet areas should be used minimally.

b. Pollution potential generated by harvesting and cultural operations can usually be minimized by selecting methods and operating schedules which result in the least disturbance or compaction of the soil, both initially and over the full span of operation. Careful location and use of tractor roads and skid trails, particularly when the ground is wet, will reduce sediment generation. As in the case of roads, skid trails should not be located in normally wet areas, nor should they utilize stream channels as part of the route, if a feasible alternative exists. Tractor roads and skid trails should be carefully located to avoid the concentration of water on long, steep grades. Careful handling of debris will prevent accumulation which tends to act as dams in streams, and results on breakup, in high stream velocities causing channel erosion. Early revegetation of disturbed areas will provide stabilization of the soil, thus minimizing erosion. Additional techniques, such as provisions for special streamside management areas, may be useful.

2. Reduction

Reduction measures to control erosion and sediment runoff generally utilize some physical, biological or chemical method or technique. They modify and reduce the unavoidable disturbances caused by an activity, for example:

a. Revegetation of cleared areas, mulching of road cuts and fills, and removal of debris from water courses.

b. Structural measures such as culverts, ditches, berms, rip-rapping, baffles, drop structures, catch basins and slope stabilization on road sites.

c. Removal of temporary bridges and culverts, removal of temporary road fills across water courses, and closing and revegetation of temporary roads and skid trails after completion of harvest and reforestation activities.

Because of the widespread nature of sediment runoff, erosion control measures must be a principal thrust of the water quality management program of each management unit. In the areas where nutrients, pesticides, and other chemicals cause particular problems in surface or ground waters, further control measures may be necessary. These measures would relate to the application timing, method, and amounts, utilization, and management of the fertilizers, pesticides, and fire retardant chemicals. Particular attention should be taken to keep chemicals away from streams. Care must be exercised to insure that thermal problems are not created in streams by excessive removal of shade canopy. Attention to proper forest management, engineering, and harvesting principles can substantially reduce pollution attributed to silviculture.

CHAPTER 3

ASSESSMENT, ANALYSIS, & BMP DESIGN FOR SILVICULTURAL PRACTICES

The methodology described in this guidance is based upon the concept that:

> Nature, in all her diversity, interacts to create different types and degrees of inherent water pollution hazards. A silvicultural activity affecting the soil's protective cover or physical conditions, or the natural drainage pattern, can amplify the inherent hazard and add pollutants to streams and other watered areas. Pollution control can be achieved most effectively when the silvicultural activities and their accompanying specific water pollution control measures are designed within the constraints and opportunities associated with the inherent water pollution hazards.

This chapter describes a nonpoint pollution control process consistent with the BMP approach and the above concept. This process consists of ten milestones. Milestones 1 through 4 are major components of problem assessment and analysis. Milestones 5 through 10 list the steps involved in the development of BMP design criteria as well as the steps leading to BMP implementation and evaluation. The process is outlined in Figure 1.

The milestones are:

1. Identification and evaluation of interactions among climatic, physiographic, and biologic characteristics of various landscape areas within the drainage, and determination of the inherent pollution hazards (hazard indices) of these areas;
2. Description and evaluation of each silvicultural activity -- where, when, and how each will be or has been carried out; the conditions each has or may create(d) on the various landscape areas; the degree

to which the affected area has recovered since the activity took place; and the change in hazard index of the affected area;

3. Description of the hydrologic, physical, chemical, and biologic characteristics of the receiving waters, both past and present;
4. Identification of the degree to which the changes in inherent pollution hazards, due to conditions created by silvicultural activities, might contribute or are contributing potential pollutants to the stream or other watered area;
5. Comparison of past trends and present character of water quality to water quality goals, and identification and definition of problems;
6. Development of the BMP design criteria needed to meet water quality goals, considering the differences in conditions created by silvicultural activities in relation to the inherent pollution hazard index of the area;
7. Identification of a range of technically feasible, alternative silvicultural practices or a mix of practices which meet these criteria;
8. Screening of the technical alternatives to identify those that are feasible considering factors such as economics, social attitudes, and needs;
9. Development of implementation schedules for the selected BMP, followed by actual implementation under appropriate regulatory or nonregulatory, and institutional arrangements;
10. Development of a feedback system to ensure the use of the most effective practical means for pollution control consistent with water quality goals.

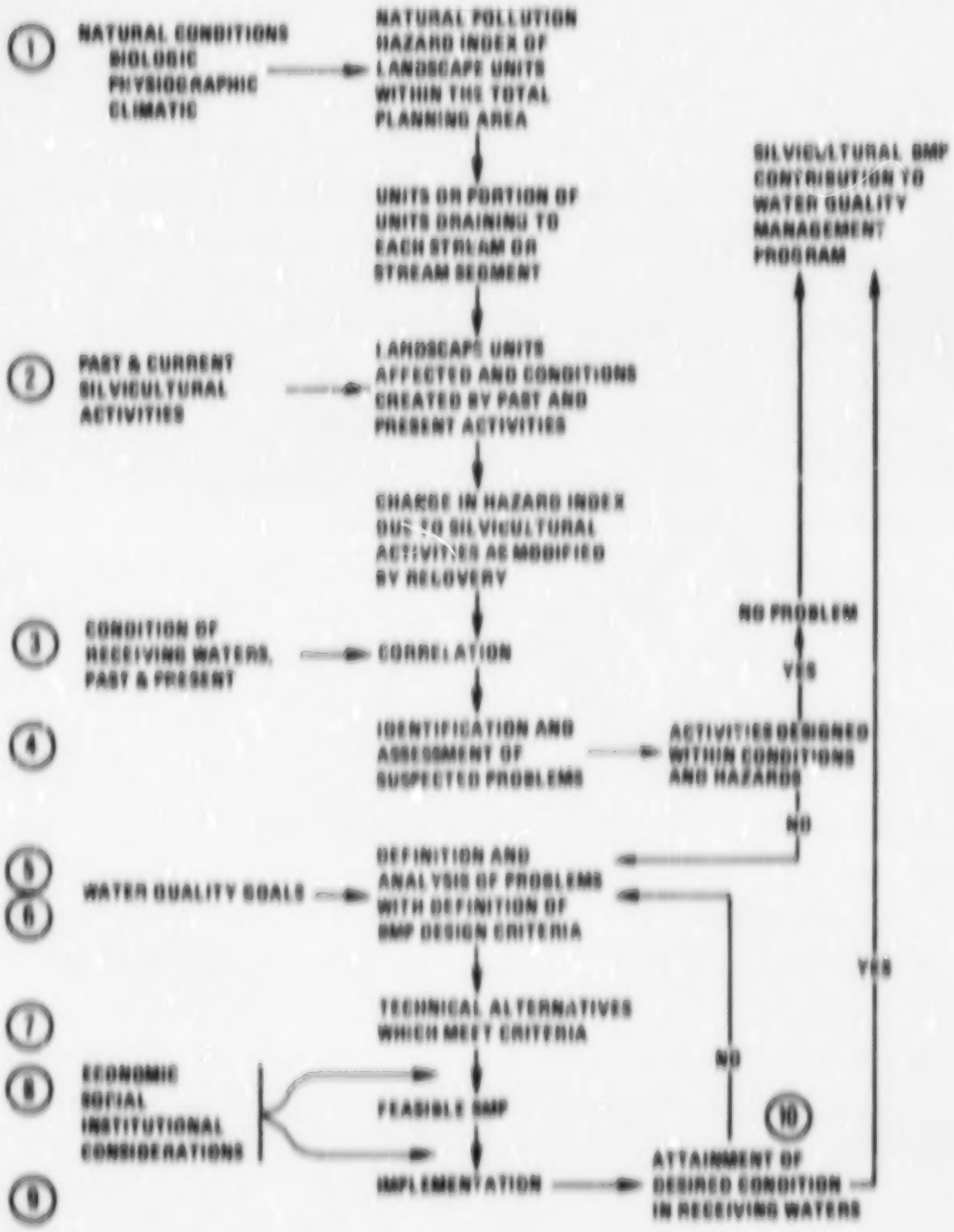

FIGURE 1. NONPOINT POLLUTION CONTROL PROCESS FOR SILVICULTURE

Assessment

An assessment should be made to determine existing and potential water quality problems. This assessment must include an identification of the types and degree of problems and the sources of pollutants (both point and nonpoint) contributing to the problem. The assessment of nonpoint sources of pollutants should include a description of the type of problem, an identification of the waters affected (by segment or other appropriate planning area), an evaluation of the seriousness of the effects on those waters, and an identification of nonpoint sources (by category) contributing to the problem.

Since the assessment is intended to lead to the implementation of a practical, effective water quality management program, it must examine the effects on water quality of past, current, and potential activities.

Determination of Inherent Water Pollution Hazards

The inherent water pollution hazard of an area is most directly associated with the combined erosion and transport processes -- primarily those involving water erosion, dry soil creep, mass soil movement, and deposition of particles. The hazard occurs as a result of the interaction between many factors, such as geologic materials, soil properties, climatic factors, shape and slope of the land surface, type and amount of protective cover, and proximity of the area to receiving waters.

Hazards are generally described in qualitative classes, such as low, moderate, high, and severe. These classes are expressed as the inherent water pollution hazard index.

Inherent water pollution hazards play an important role in establishing the natural hydrologic, physical, chemical, and biological characteristics of surface waters.

They also play an important role in determining the degree to which the different kinds and combinations of silvicultural activities, carried out by man, affect characteristics of surface water, and result or do not result in pollution.

1. Climate

Climatic variables make up the most important driving force for generation of nonpoint source pollution since they provide the energy for both detachment and transport of potential pollutants. However, climatic variables are the most difficult to assess because they are not fixed in either time or space. Averages, particularly those based upon short records, can be very misleading.

Figure 2 illustrates a situation in which the use of average monthly amount of rainfall alone would have led to erroneous conclusions regarding the timing of climatic conditions associated with pollution generation. The figure, based on 30 years of data for the area, shows the greatest amount of rainfall was in February and March; however, the most intense rains occurred during June and July which actually was the time that climatic conditions were most influential in pollution generation. The 30-year average information only helps us to look for the important data.

The evaluation of climatic variables for pollution control planning and BMP design should focus on those features which are the most significant to the pollution-generating process during the time required for the site to recover to its pre-activity pollution-potential level. For example, in some cases the significant climatic factor may be the amount, duration, and intensity of rainfall associated with summer thunder storms or with general frontal storms which can be expected with a certain frequency. In other cases, it may be spring snowmelt or spring rains on frozen ground.

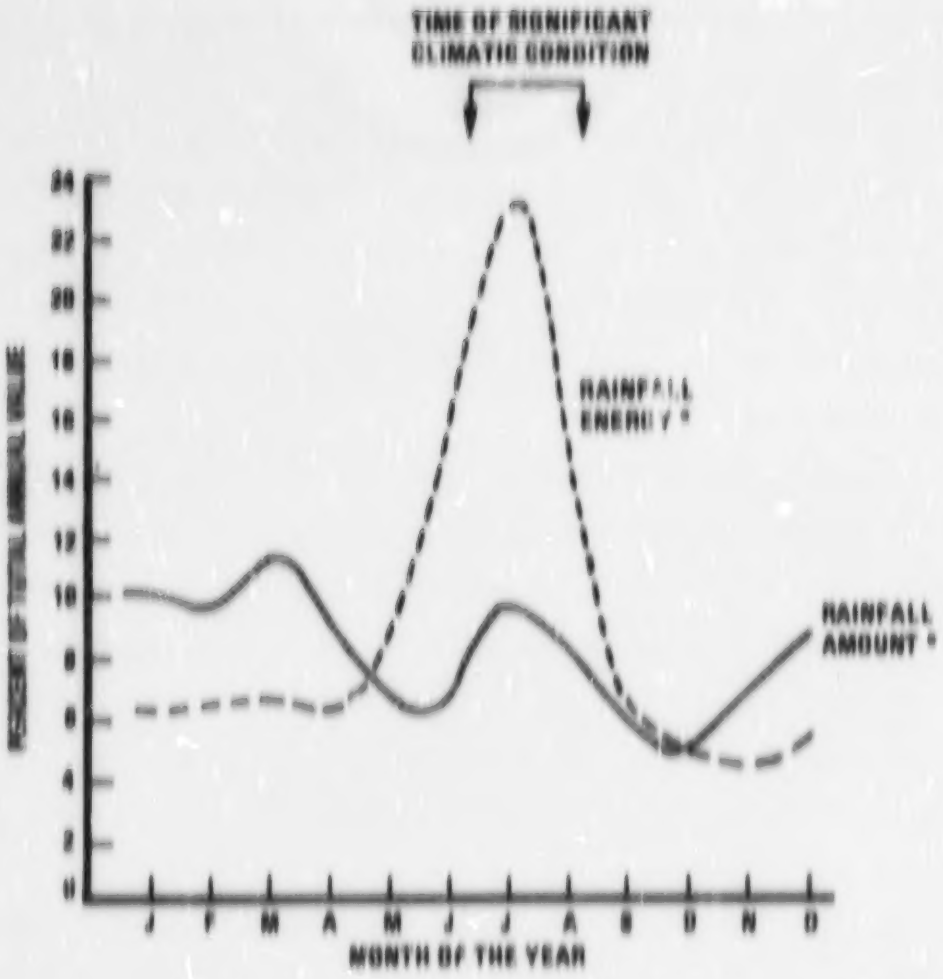

FIGURE 3.

EXAMPLE OF A SITUATION WHERE FAILURE TO EVALUATE RAINFALL INTENSITY AS WELL AS RAINFALL AMOUNT COULD LEAD TO IMPROPER B M P DESIGN

* NOTE: THESE DATA WERE BASED UPON MONTHLY AVERAGES, 1930 – 1980 FOR THE EXAMPLE AREA.

3. Physiography

Physiographic features of an area affect the way in which water is distributed once it falls upon the land. Included among these features are characteristics of landform, geology, soils, and topography. Some of these characteristics, particularly those of the geologic materials and soils, are also key to the surface flow potential of the area. This is true not only for the natural state but also when the area is impacted by silvicultural activity. Effective pollution control planning and implementation depends to a large extent upon proper interpretation of the processes such as detachment, transport, and nutrient cycling.

4. Biology

Biological features, particularly those associated with plant communities on the land, are important considerations in pollution control planning, because of their interaction with climatic and physiographic features in the detachment, transport, and nutrient-cycling processes. The specific combinations of plant species within biological communities are reflected in such features as the form and density of the forest vegetation, the type and amount of associated ground cover, and the soil-holding ability of root systems. Many of these features can be modified by silvicultural activities. Therefore, proper interpretation of how and to what extent biological communities and their modification by man affect the pollution-generating process, is important for development of appropriate water pollution prevention and reduction practices.

Interpretation and Analysis

Without proper interpretation, raw data make little, if any, positive contribution to the decision-making process. However, when placed in a water quality perspective by trained and experienced professionals of the

appropriate disciplines, these data begin to take on meaning. The relative hazards to various areas as expressed by different combinations of climatic, physiographic, and biologic features can be expressed on hazard index maps. These maps are valuable in determining the most probable source of existing sediment pollution and evaluating the potential amplifying effect of present and proposed activities on sediment production.

Timing factors are important considerations in water pollution control. For example, heavy runoff storms, occurring when streamflows or lake levels are low, often result in degradation of water quality. The potential for degradation should influence the timing of scheduled silvicultural activities.

Receiving Waters

The present hydrologic and quality characteristics of receiving waters and their associated aquatic environment reflect not only the long-term interaction between the climatic and the variety of natural features of the drainage area, but also the short-term and long-term effects of man's past and current use of the watershed and its waters. The relative contribution of nonpoint source pollutant loads in the water, both natural and man-caused, needs to be placed in perspective since water quality management planning in silviculture focuses on the control of man-caused aggravated conditions and their expedient recovery.

The inherent hazard index scheme provides a logical approach for a preliminary assessment of man-caused sources of pollution. More important, preliminary assessment can be verified or adjusted through field checking, if deemed necessary. Sensitivity of receiving waters and their associated aquatic environment to changes in pollution loads also needs to be determined or monitored so that appropriate modification of BMP can be developed and applied. Of particular importance are those waters that are close to exceeding water quality requirements. For example, a slight increase in

pollution that only changes the habitat of a stream organism for a short time may still be sufficient to cause eradication of that organism. A particular silvicultural practice may contribute only a minute portion to the total pollution load of a large drainage area, but still cause a devastatingly adverse effect on a headwaters' tributary within that drainage.

Interactions

A wide range of inherent water pollution hazards exists due to the many combinations of conditions that are associated with climatic, physiographic, and biologic factors and their influence on the receiving waters. The inherent hazard can be very low or perhaps even nonexistent in areas of flat terrain, highly stable soils, low-intensity precipitation, and abundant, rapid-recovering ground cover. At the other extreme are the high hazard areas which are characterized by steep slopes, highly erodible soils, high-intensity rainfall, sparse ground cover with slow recovery time, and drainage into highly sensitive streams.

In some cases, the hazard may be associated with only one critical condition such as sensitivity of the receiving waters or intensity of rainfall. More often, the pollution hazard is generated by the simultaneous occurrence of critical conditions in two or more interacting factors. Many combinations are possible. An extreme combination, illustrated in Figure 3, shows percent of total annual rain intensity and duration (energy) and percent of total annual streamflow in relation to their simultaneous occurrence on an area with highly erodible soils and steep slopes. This information is presented in a schematic illustration to the right of the figure.

The planner and the forester must work closely together to define the hazard index and to assess and analyze the effects of silvicultural activities in relation to those hazards so that BMP design will be effective and implementable.

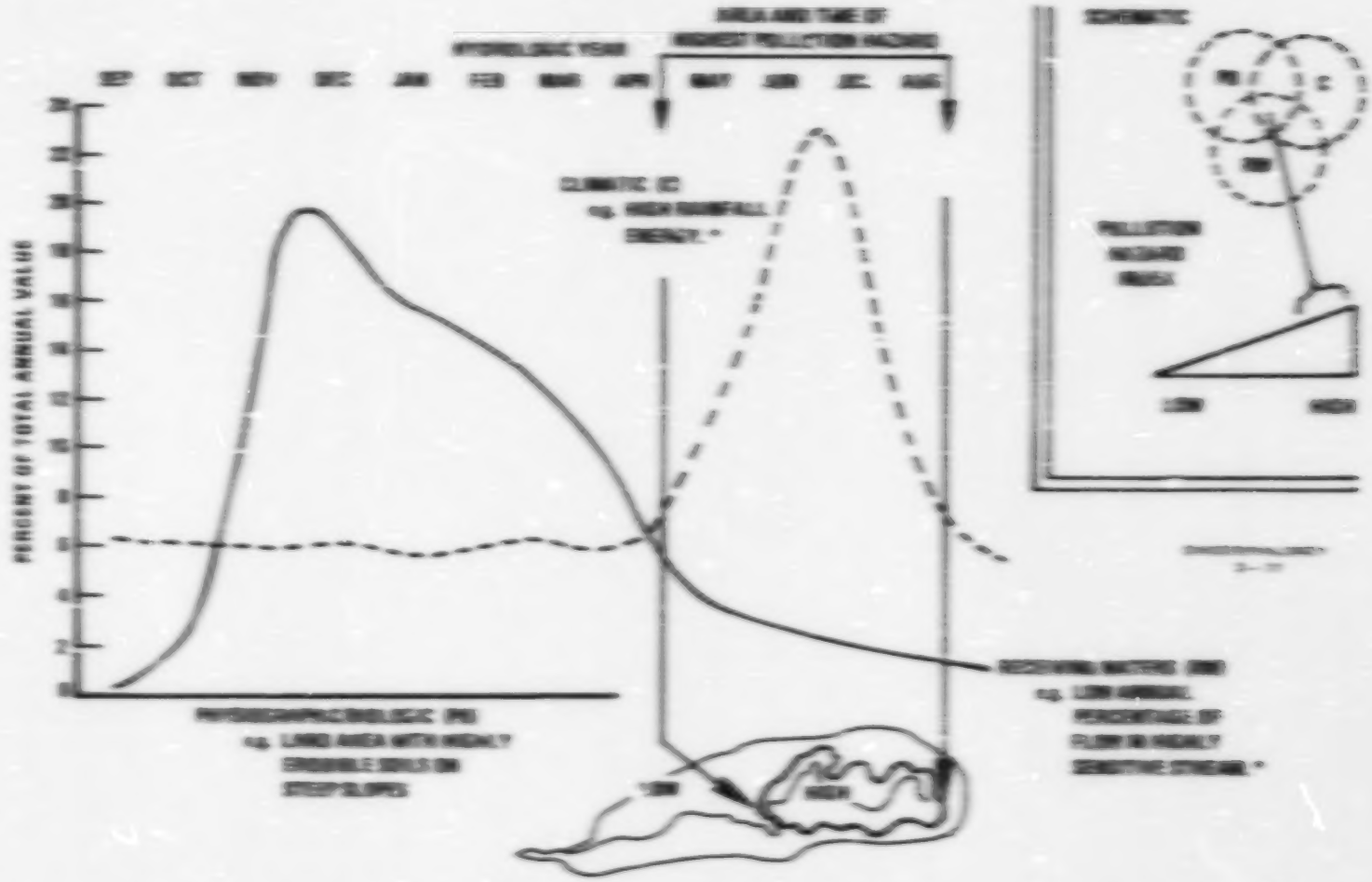

FIGURE 3. EXAMPLE OF A SITUATION WHERE THE SMALLEST POLLUTION HAZARD IS EXTREMELY HIGH DUE TO THE HEAVY INTENSE RAINFALL ON HIGHLY ERODIBLE SOILS ON STEEP TERRAIN AT A TIME WHEN STREAMFLOW OF A HIGHLY SENSITIVE STREAM IS LOW

*NOTE: THESE DATA WERE BASED UPON MONTHLY AVERAGES, 1939 – 1968 FOR THE EXAMPLE AREA.

Pollution control management must recognize the presence or absence of pollution-causing interactions on an area-specific basis as well as on a time-specific basis. Then, each of man's silvicultural activities can be designed in the context of the inherent water pollution hazard.

Activity Identification and Evaluation

Silvicultural activities are often carried out in conjunction with or in the same general area as activities such as construction, mining, waste disposal, and agriculture. Therefore, a screening process is necessary to identify and assess water pollution problems related specifically to silvicultural activities in order to design and monitor silvicultural BMP.

The initial screening should identify drainage areas that have (1) receiving water segments with nonpoint source related water quality problems and (2) silvicultural activities. This should be followed by further screening to identify the type of silvicultural activity(s), the inherent water pollution hazard(s) on which the activity occur(s), the condition(s) the silvicultural activity has created, and the relation of these conditions to the identified water quality problem. The BMP should be designed to prevent or reduce potential pollution from silvicultural activities regardless of any other activities in the area.

To serve as a basis for BMP development, additional technical information is needed. This may include information about the area and the silvicultural activities such as an assessment of the methods and equipment used, the specific techniques applied, the timing of the operations, the characteristics of the area, the time required for an adequate protective cover to develop naturally, and the proximity of the activity to receiving waters. Where applicable, subsequent use(s) of the area, such as hunter

use of stabilized skid trails, should also be examined. Since these subsequent uses may cause more damage than the original use of the area, they must be considered in BMP development.

Establishing Appropriate BMP Design Criteria

The procedure outlined in the preceding sections provides a context for (1) objectively evaluating each existing water pollution problem that is associated with silvicultural activities, and (2) identifying the differences in pollution-generating conditions created by various silvicultural activities based upon the inherent pollution hazard of the area and the operational techniques employed. Planners, foresters and persons from allied disciplines can use this information and establish jointly appropriate BMP design criteria for current and future activities.

BMP design criteria should recognize how natural pollution hazards vary on different areas of land and how the factors which create the hazards interact. Local persons of appropriate scientific disciplines may be needed to adequately appraise and interpret this information.

BMP design criteria can be divided into two categories: those that can be followed in most communities and those that can be carried out only to the extent feasible in some areas. The kinds of criteria selected should minimize or prevent potential pollutants generated on the land from reaching the waters at a critical time, and in amounts which are inconsistent with water quality goals.

Some examples of BMP design criteria are:

1. Minimize, to the degree feasible through proper scheduling of operations, the extent of unprotected soil surfaces on high-hazard areas during periods when heavy rain and/or heavy surface water runoff is most likely to occur;

2. Ensure that the maintenance schedule for the access system includes emphasis on high-hazard areas and provisions for adequate water-runoff control, cleaning of culverts, and needed reinforcement of erosion control measures, immediately prior to and during periods when heavy rain and/or heavy surface water runoff normally can be expected;
3. Ensure the establishment of appropriate operational controls to prevent the creation of pollution-generating conditions, such as deep wheel tracks in roads, during wet weather when immediate corrective action is not practical;
4. Ensure that appropriate water pollution control practices for the optimum dissipation of rainfall and runoff-energy are completed prior to times of the year when heavy rain and/or heavy surface water runoff normally can be expected in road or access areas as well as in harvest areas;
5. Allocate, to the extent feasible, the access elements creating greatest disturbance to those land areas with the lowest inherent pollution hazard;
6. Minimize disturbance of vegetation on areas outside the actual area of access-road construction;
7. Adopt road design standards that minimize the creation of large road-cut and fill sections;
8. Apply stringent design and construction standards at points where the access element crosses receiving waters or crosses high-hazard areas close to receiving waters;

9. Ensure that heavy equipment is operated only in preplanned locations, which are carefully selected to minimize the equipment's use on high-hazard areas;
10. Schedule activities and adopt methods of operation which result in the least amount of active site disturbance during wet weather;
11. Identify, before field operations begin, streamside management areas and the specific operating techniques and equipment constraints applicable to these areas;
12. Ensure that temporary culverts, bridges, or other protective measures are used where stream bottoms or banks would be otherwise damaged, and that these protective devices are removed after use;
13. Design the access system to minimize, to the extent feasible, the number of stream crossings. Carefully choose the place of crossing to minimize stream damage, rip-rap and buttress fills for bridge approaches and assure adequate culverting to accommodate high flows;
14. Explore all possible alternatives before logging across streams, and where no other feasible alternative exists, find crossing sites that have low, stable banks; firm stream bottoms; and gentle slopes along the approaches; and
15. Ensure that all forest chemicals and pesticides are used in accordance with regulations and manufacturer's direction and that care is taken to prevent their accidental discharge into stream and other watered areas.

CHAPTER 4

POLLUTION CONTROL PRACTICES

As previously stated, water pollution control BMP's generally involve a combination of prevention and reduction practices which are built into the interrelated activities of the access system, harvest system, crop regeneration methods and other intermediate practices. These prevention and reduction practices modify some aspect of the interactions among land capability, each silvicultural activity, the conditions created, the natural mechanisms affected (e.g., erosion, runoff, etc.), and the associated pollutants.

The examples in this chapter will illustrate a few of the many practices which in various combinations may (1) limit the generation of conditions that could add materially to the pollution potential, (2) reduce the unavoidable pollution potential created by man's activities and/or (3) prevent the transport of unnatural and undesirable material from a disturbed area to receiving waters. These practices generally fit within the broad framework shown in Table 1. The reader will undoubtedly be aware of many more that are applicable to his or her local situation. Due to the complexity of the interaction among all the variables and among the various practices themselves, the planner should seek competent advice and recommendations from appropriate professionals, experienced forest owners, and forest managers to develop a feasible BMP for the solution of a particular water quality problem and for the prevention and/or reduction of pollution. A practice or mix of practices that could be a feasible solution to a potential pollution problem in one situation, may not be feasible in another, or may even aggravate the problem. Thus, the feasible, implementable BMP, must be determined on a site-by-site basis with full consideration of overall management objectives.

TABLE I

FRAMEWORK FOR WATER POLLUTION CONTROL PRACTICES USED IN CONNECTION WITH

SILVICULTURAL ACTIVITIES

Water Pollution Control - Type of Prevention and Reduction Measures

PREVENTION	REDUCTION
Limiting, through prevention or management decision measures, the generation of conditions that could add materially to the pollution potential.	Applying physical, biological, or chemical measures to help reduce the unavoidable pollution potential created by activities and/or prevention of potential pollutants to receiving waters.
Advance planning to avoid, to the extent feasible, potential problems through identification of, and allowance for: [1] natural hazards such as areas of natural mass earth movement, highly unstable soils, and unstable stream channels, [2] limitations imposed by landform, climate, topography, soil moisture, channel characteristics, etc., [3] land capabilities in terms of soil productivity, vegetation recovery potential, etc.	• Erosion Control — on-site Revegetation Dispersion of concentrated runoff Physical or chemical treatment of the soil or temporary soil treatment (mulching, etc.) — in-channel Debris removal Structural measures
Consistent with overall land management objectives, including due consideration for the other resource values of the area and the technical, economic, institutional and social feasibility and practicality of alternatives:	• Nutrient Management Prudent use of fertilizers Treatment of forest residues
• minimize type and magnitude of disturbance in high hazard areas.	• Pesticides Management Prudent use of pesticides
• select appropriate operational methods, standards, and equipment with due consideration of relevant limitations	• Water Temperature Control Streamside vegetation management
• optimize size and shape of areas and the sequence, timing, spacing, and intensity of activities.	

Prevention Practices

Pollution prevention practices should be carefully thought out during the planning stage rather than relying only on adaptive techniques developed during the actual silvicultural operation. Thus, these practices can be applied under a wide variety of management alternatives to meet a number of objectives.

Most of the activities associated with the harvest system, crop regeneration, and intermediate practices are areal in nature. For example, the area affected may vary widely in both size and shape and may occur almost anywhere on the forested landscape. Generally, these activities reflect different time frames and operational methods and result in relatively short periods of actual on-the-ground disturbance followed by recovery of the site to the previous condition. During the operation and recovery period there may exist great potential for water quality degradation. Other types of silvicultural activities create a more permanent type of disturbance. This is particularly true of those activities associated with the access system when it requires repeated treatment, such as maintenance of the road bed, drainage features, and proper sight distance.

Following is a list of the general types of prevention practices. Particular attention is paid to how these practices relate to water pollution control. They are:

1. Correlate road and harvest plans to obtain the combination that will minimize the potential for nonpoint source pollution;
2. Locate access routes to avoid, to the extent possible, high-hazard areas, such as those known to contain a potential for landslides, highly erodible soils, and unstable stream channels. This is the most effective of all practices since the effects of poor location often

cannot be overcome through project design or use of reduction practices:

3. Time construction at stream crossings to minimize direct impact on the stream;
4. Design roads to minimize large cuts and fills immediately adjacent to stream channels, i.e., make the road fit the topography;
5. Provide for adequate surface and subsurface water control;
6. Provide for adequate reduction measures where high-hazard areas cannot be avoided;
7. Surface roads where this practice is consistent with other land-management objectives and where the natural roadbed is composed of highly erodible material, particularly on those sections of road immediately adjacent to or crossing stream channels;
8. Schedule clearing, preliminary excavation, and erosion control work to minimize, to the extent feasible, the area of bare soil that at any one time is subject to uncontrolled runoff during protracted periods of normally heavy intense rain and/or intense runoff;
9. Schedule herbicide applications at other than periods of normally heavy rain or runoff;
10. Locate and lay out timber harvest areas to minimize the intensity of activities and use on high-hazard areas, particularly those immediately adjacent to stream channels;
11. Select the proper operational methods and equipment for the specific site conditions;
12. Schedule activities in both time and space to control the amount of disturbance in any given watershed at any one time;

13. Minimising use of pesticides and other chemicals and carefully analyse their need before application;
14. Minimise the use of practices which increase infiltration or concentration of water in areas where mass soil movement (landslides) is a hazard; and
15. Preplan operational controls for sensitive areas such as streamside, including management direction and operational stipulations regarding the type and method of operation within these areas. Stipulate operational procedures which could be appropriate within the streamside management area, such as:
    - Maintain sufficient amount of natural ground cover and density of trees or other vegetation along streams to protect against thermal pollution, streambank erosion, and the direct movement of potential pollutants into the stream channel;
    - Locate landings, skid trails, and tractor roads to avoid paralleling stream channels for long distances; to minimise the number of channel crossings; and to avoid dragging logs down existing drainage channels or creating artificial drainage patterns;
    - Use culverts of sufficient size to accommodate high-flow conditions;
    - Fell trees away from the drainage along perennial and intermittent water courses; and
    - Inspect periodically stream crossings and drainage systems to insure the clearing of channels and culverts for maximum discharge capacity.

The photographs in Figures 4 through 10 show examples where advance planning has been utilised for pollution prevention.

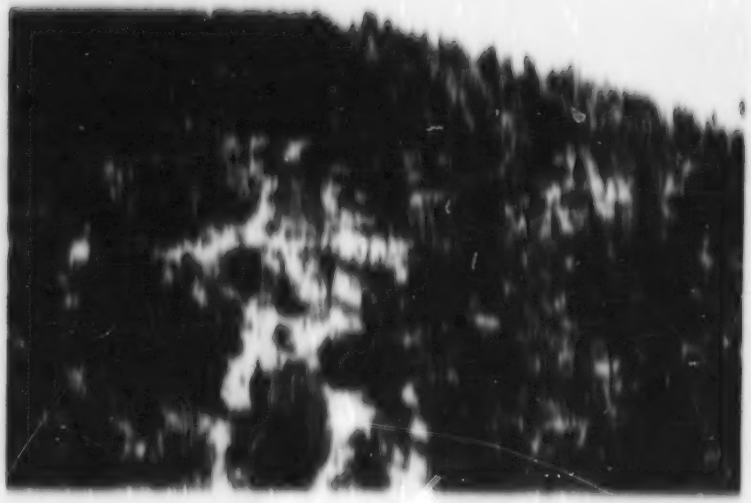

FIGURE 4 - TRACTOR HARVESTING OPERATION

This is a cut-over area on very steep ground with slopes up to 70 percent, but with inherently stable soils, in an area of low intensity and well distributed precipitation. As a result of careful planning and advance location and construction of the road and tractor trails, logging has been done without significant erosion or other damage to the watershed.

FIGURE 5 - CABLE HARVESTING OPERATION

A timber-harvesting operation where terrain features, relative costs of alternatives and management objectives have made the use of high-lead cable system advisable and feasible. Note the fan-shaped pattern created by drawing the logs uphill to a central point. This pattern disperses runoff over the slope and reduces potential for erosion. Cable systems are expensive to implement and are most commonly used where forest regeneration objectives require clearcutting and when large volumes of timber are to be harvested on steep terrain where road building is to be minimized.

FIGURE 6 - PREPLANNED STREAMSIDE MANAGEMENT AREA

The slope at left was heavily cut. Streamside management areas like the one illustrated, within which only carefully selected activities may be carried out, help maintain water quality and preserve favorable conditions for fish, wildlife, and recreation where these values are important.

FIGURE 7 - WELL LOCATED MAIN ROAD

Well-located main road that is constructed around edge of meadow, avoids damage to water quality.

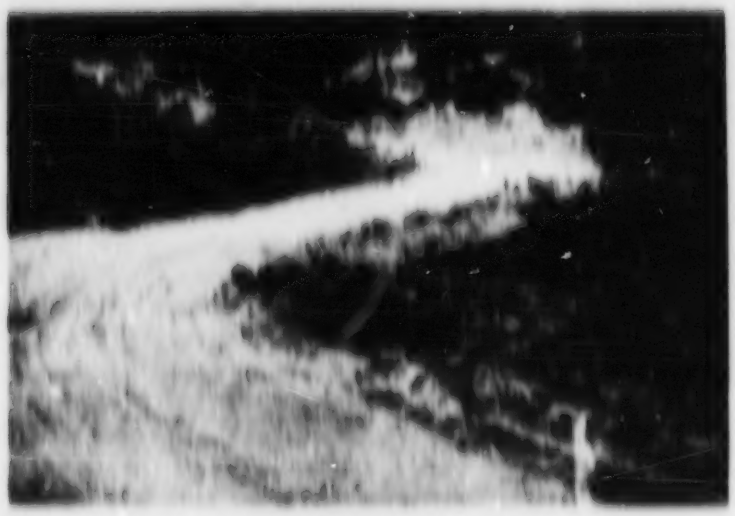

FIGURE 8 - ROAD CROSSING A MEADOW

Good example of road crossing a meadow with minimum disturbance. Crossing is located at a narrow point of the meadow and has a metal culvert (hidden by log at far side) large enough to carry runoff from local watershed. Note that fill is raised above meadow level, the fill material having been hauled in, and that no excavation has been made in the meadow.

FIGURE 9 - LOW USE ROAD

A low use road located and built to conform to the landscape with minimum soil disturbance. The location and design evidence consideration for the erosion values of the soil types, in this case a sandy soil, as well as other management objectives.

FIGURE 10 - TRACTOR ROAD

Tractor road adjacent to creek. Good location, well above high water level, with a fringe of streamside vegetation, rolling road surface to minimize water concentration, and no unnecessary soil disturbance. All logs from a large area were arch-skidded over this road to a single prepared crossing just below this spot.

Reduction Practices

1. Practices to Reduce the Erosion Potential

Sediment produced by erosion is generally recognized as the greatest pollutant from nonpoint sources. Erosion of soil by water can take a variety of forms. On the land surface, erosion may consist of sheet erosion, rill erosion, and/or gully erosion. In the stream channel, erosion may consist of streambank erosion and/or channel downcutting. Mass soil movements may also occur in various forms such as landslides, mudflows, or downward creep of entire hillsides.

Man alters natural surface erosion primarily by removing, changing, or adding to the vegetative cover; by physically disturbing the soil; and/or by changing the way water moves over the land surface. Stream channel erosion is altered by activities which produce changes in the volume, timing, duration, and/or velocity of water flowing in the channel, or by activities which disturb the channel bank or bed. Natural mass soil movements can also be accelerated or impeded, to some extent, by man's activities, particularly those which affect debris in stream channels; subsurface water movement; weight on the land surface; and root systems of trees and other vegetation which help to bind the mass together. In many forest situations adequate ground cover regenerates naturally within the first year after disturbance, thus providing surface erosion control. However, if road cuts are too large, slopes too steep, and soils highly erodible, even this short time span may be sufficient to create pollution. Generally, vegetation must be developed as quickly as possible to prevent erosion. Table 2 lists the principal types of erosion control practices applicable to silvicultural activities, their general types of application, and some of their favorable and unfavorable features. The photographs in Figures 11 through 14 illustrate a few of these reduction practices as they have been applied to meet specific local conditions and management objectives.

TABLE 2

PRINCIPAL TYPES OF REDUCTION PRACTICES FOR EROSION CONTROL APPLICABLE TO SILVICULTURAL ACTIVITIES WITH SOME FAVORABLE AND UNFAVORABLE FEATURES IN TERMS OF WATER POLLUTION CONTROL

Erosion Control Practice	General Types of Application	Some Favorable and Unfavorable Features
Seeding or planting of grasses or other herbaceous vegetation	Bare soils or soils with inadequate cover where tree reproduction is not desired (short-lived forbs, grasses, or legumes where tree establishment is desired). Not an effective technique for controlling pollution caused by landslides or other forms of mass soil movement.	Provides a relatively quick cover which decreases soil erosion, improves infiltration capacity of the soil, and may reduce overland flow of water. Relatively inexpensive. May require fertilization for establishment and growth. Grasses and other long-lived vegetation usually add to reforestation difficulty.
Seeding or planting of trees or other woody vegetation	Bare soil or soils with inadequate cover	Improves infiltration capacity of the soil and aids in reducing overland flow of water after litter layer of natural materials develops. Often takes 5 years or more to become effective. Can result in decrease of water yields under some circumstances. Moderate initial cost. May require fertilization for proper growth and vigor.
Dispersal of runoff concentrated by man's activities	Tractor roads, skid trails, and logging roads	Retards surface runoff by reducing slope length and area of concentration. Permits infiltration of water as it is spread onto stable surfaces. Can increase soil erosion if water is directed to unstable areas where it cannot spread and infiltrate. May require installation of energy dissipators. Moderate initial cost and some maintenance costs.

TABLE 2-Continued.

Erosion Control Practice	General Types of Application	Some Favorable and Unfavorable Features
Physical treatment of the land or soil to improve infiltration or detain runoff (contour trenching, furrowing, etc.)	Areas where soil moisture or rapid surface runoff inhibit adequate plant establishment and growth	Retards surface runoff by reducing slope length and area of concentration. Increases infiltration and improves soil moisture on treated areas thereby aiding plant establishment and growth. Loses effectiveness and can result in greater soil loss if these practices fail. Substantial initial cost and some maintenance costs.
Debris Removal or Dispersal	Stream channels	Reduces concentration of organic materials. Removal from stream channels lessens chance of debris dams and sediment deposits forming and subsequent streambank erosion. May result in damage to stream banks and stream bottoms if not carefully done. Must be coordinated with fisheries habitat and other land management objectives. Moderate to substantial cost.
Mulching	Bare soils or soils with inadequate cover where steepness of slope or soil moisture conditions are critical	Aids in maintaining soil moisture and reduces the rate of overland flow, thereby allowing more water to infiltrate within the soil capacity. May have a positive or negative influence on nutrient addition depending on physio-chemical environment. May also result in a higher BOD load if washed into receiving waters. On some soils, increases need for nitrogen fertilizers. Moderate cost.

TABLE 2 - Continued.

Erosion Control Practice	General Types of Application	Some Favorable and Unfavorable Features
Structural measures such as debris basins, sediment ponds, retaining walls, water flow retarding structures, etc.	Stream channels, areas of mass earth movement	Retards the movement of water and associated pollutants from the land to receiving waters and/or within stream channels. Possibility of some additional pollution during construction. Moderate to substantial installation and maintenance cost.
Chemical treatment of soil (flocculants or surficants)	Certain fine textured soils and/or soils which are difficult to wet	Application of flocculants on certain fine textured soils causes aggregation of soil particles which improves infiltration capacity and aids in reducing overland flow of water. Pollution potential of chemicals vary and in many cases are unknown. The effectiveness of some flocculants is inversely related to clay content. Application of surficants which reduce the surface tension at the water/soil interface have been used with varying degrees of effectiveness for improving initial infiltration rates of some soils. The pollution potential of many surficants is unknown.

FIGURE 11 - MULCH ON ROAD FILL

A mulch of forest litter, in this case mostly pine needles, applied to a depth of two inches to this road fill slope has provided immediate protection against erosion. The seeds of trees and shrubs which such litter usually contains will provide permanent cover. This type of inexpensive treatment is often appropriate on logging roads where erosion proofing is required.

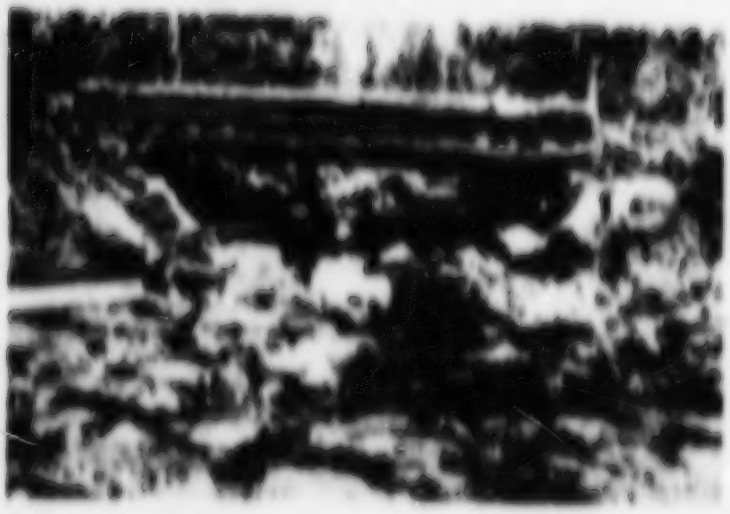

FIGURE 12 - LOG BRIDGE

All stream crossings should include culverts, bridges or other measures to allow proper passage of water. This log bridge on temporary logging road will accommodate high-water flows without damaging the road or stream channel. Because green, unpeeled logs were used, this bridge will have a short life. At the end of the period of log hauling this structure can be removed without damage to the channel banks.

FIGURE 13 - ABANDONED LOGGING ROAD

An abandoned logging road which was planted with clover seed after water control measures were installed to prevent accelerated water runoff. Clover was used in this case to meet multiple management objectives, including improved game habitat as well as erosion control.

FIGURE 14 - LOG-HAUL ROAD

A log-haul road has been "put-to-bed" until needed at some future date. This road was outsloped and provided with broad-based dips to break up long slopes and disperse runoff. Where feasible and needed, this type of road can often be blocked to prevent undesirable and damaging use. It also can be planted with various types of vegetation to further protect against possible soil erosion.

8. Nutrient Management Practices

Nitrogen and phosphorus are the primary nutrients that may be affected by silvicultural activities. If not carefully controlled, additions of plant residues and fertilizers by man may increase the level of these constituents above their natural levels in streams within and below forested areas.

Nutrient cycling is an important component of the complex and interrelated processes which are going on continuously within forest ecosystems. Nutrients are directly related to the soil-formation process and to soil productivity. During the cycling process, excess amounts of organics and inorganics may be moved from the land by direct runoff; by leaching and discharge via ground water/subsurface systems; and by association with sediment from erosion. Depending on the site, pollution problems resulting from the use of nitrogen are significantly different than those resulting from the use of phosphorus. Practices which reduce direct runoff and/or erosion also are effective in reducing the transport of excessive amounts of nutrients to receiving waters. However, in cases where the most important transport mechanism is leaching and discharge via ground water/subsurface systems, such as highly porous geologic materials or areas with high water tables, additional and/or alternative practices will have to be used to achieve the desired level of control. These alternative practices involve modified use of fertilizers and methods to dispose of forest residue.

9. Control of Nutrient Pollution from Forest Fertilization

Application of chemical fertilizers to sizeable areas of commercial forests as a means of stimulating growth of new plantations or established stands of trees, while still a relatively minor operation, has, in some areas, expanded rapidly over the past few years. Fertilizers are also applied to forest lands for a number of other silvicultural purposes such as:

- To increase the production of seed from selected trees within a forest stand or from genetically selected groups of plants within a tree seed orchard;
- To improve color, needle retention, and growth within Christmas tree plantation;
- To improve vigor and survival of seedlings;
- To aid survival and initial growth of individual tree plantings; and
- To aid establishment and growth of vegetation and road cuts and fills.

Forest lands differ from agricultural lands in their relative susceptibility to loss of fertilizer nutrients to surface and ground waters. In most, but not all cases, nutrients on forest sites are less of a potential pollutant. This is usually attributed to: (a) the difference in frequence and amount of application, (b) the difference in soil and site characteristics, (c) the longevity and growth habits of the plants and the degree and continuity to which they occupy the site, and (d) the retention, utilization and cycling of nutrients by the biomass of the forest vegetation.

Nutrient pollution from fertilization on forest lands is controlled by using techniques which avoid direct application to the surface waters and immediate riparian zone. Also involved are the elimination of excessive applications, the selection of proper fertilizer formulation, and the proper timing and method of application.

The key factors in the selection of the type of fertilizer and the method of application which are most appropriate for pollution control are local soil nutrient deficiencies, physical condition of the soil, plant species requirements, cost factors, weather conditions, access, and topography.

4. Control of Nutrient Pollution Through Treatment of Forest Residues

Forest residues accumulate as a result of natural mortality of forest vegetation and of land-management activities, including silviculture. These residues represent both negative and positive environmental values and, to the land-owner or manager, they may be both an impediment and an environmental variable that can be manipulated to advantage. Forest residues play a complex role in the forest system, acting as a source of soil nutrients, a fire hazard, an eyesore, a protective cover to the soil, an obstruction to the movements of man and animals, and a source of food, shade and shelter for some wildlife species. Forest residues may also be potential sources of insects, pests, disease, air and water pollution. They also provide additional fiber and habitats not only for game animals and fish but also for the microflora and microfauna essential to the forest ecosystem. Both the geomorphology and the vegetative association of any given location influence the creation and treatment of forest residues.

Many methods of treating forest residues, particularly residues resulting from timber harvesting, have been used in various parts of the country. Generally these methods are designed to increase utilization, lessen fire hazard, prepare seedbeds, remove obstacles to planting, improve scenic quality of the area, and rehabilitate stream channels. The chief treatment has been burning either over an entire cutting area or in selected locations with or without some effort at concentration of the residue. Large residue material, such as stumps and portions of cut trees which are unsuitable for timber, may be turned into other marketable products such as wood chips. Residue may also be disposed of or changed in physical form by mechanical means, or it may be left without treatment, subject only to the natural decomposition processes.

Varying environmental conditions and management objectives indicate different treatments for forest residues. Selection of practices for treatment of residues resulting from silvicultural activities, in terms of the prevention and reduction of water pollution, should include the following considerations.

Burning -The prescribed use of fire to modify a forest stand or to reduce the volume of forest residue to some desirable level, involves careful planning and determination of specific weather and fuel conditions to achieve the desired environmental and management objectives. Thus, prescribed burning is specifically located, confined in area, carefully timed, and regulated in intensity. In addition to the water pollution control measures discussed in this chapter, the air pollution aspects of burning must also be considered.

Fireline construction and snag felling around the perimeter is a common practice to confine burning to the prescribed area. On flatter terrain the fireline is usually built by a bulldozer or a tractor equipped with a blade. On areas too steep for a tractor, the line may be built by hand. Roads, interconnected skid trails, and chemical fire retardants may also offer good means of controlling or marking the desired bounds of fires.

Practices to control water pollution potentials generated by prescribed burning include:

- Construction of water diversions on firelines in hilly or steep terrain to drain the water into areas outside the burn;
- Removal of residue from natural water-concentration areas prior to burning (dips in the terrain not normally considered water courses);
- Provision for an adequate strip of undisturbed surface between the prescribed burn area and water courses;

- Avoidance, to the extent possible, of intense fires on soils that are immature, highly erodible, and/or subject to the development of a "nonwettable" condition; and
- Avoidance of the use of chemicals over or immediately adjacent to stream courses.

Piling residues for burning by hand or machine has long been the practice in some areas. In some cases the residue is bunched in piles; in others it is windrowed by a bulldozer into more or less regularly arranged rows. Many mechanical methods have been used, and some are still being developed, for example, the use of pits or bins for the burning of forest residue.

Pollution control practices where residue is piled and burned include:

- Avoiding use of equipment exerting heavy ground pressure when the soils are wet and subject to compaction;
- Avoiding location of piles within the normal high-water flowage areas of natural drainageways and water courses;
- Placing piled material in rows as nearly as possible on the contour;
- Keeping the rows fairly short and staggering them so that there is no continuous opening up and down the slope;
- Minimizing the amount of soil in the rows or piles by using tractors that have special "brush" blades with teeth;
- Avoiding the filling of water concentration areas; and
- Back-blading on the contour in hilly or steep terrain to remove all uphill and downhill tractor ruts developed during the piling or windrowing activity.

Residue Removal and Disposal - This practice is used predominantly to remove large pieces of residue from cut-over areas. Most residue

removal and disposal operations follow regular yarding of merchantable forest products.

Pollution reduction practices in terms of water quality management would restrict to the extent feasible under local conditions, the use of equipment that exerts heavy ground pressure during periods when soils are wet or when soil compaction potential is great.

Re/rranging Residue - If land management objectives can be met, and if the volume and size are suitable, residue may be rearranged or mechanically treated and left. Such procedures might be appropriate when fire is a problem and when the maximum amount of organic material for soil protection and nutrient source outweighs other considerations. Rearranging residue includes treatments such as chipping, crushing, lopping and scattering.

Pollution control practices include:

- Disposal of material well away from stream courses;
- Restriction of use, to the extent feasible, of equipment exerting heavy ground pressure on wet or very moist soils;
- Dispersion of the material over as wide an area as practical; and
- Removal of undesirable material from stream channels and dispersion of that material over the area.

5. Pesticide Practices

Aerial and ground applications of pesticides are used in forest management to control insects, rodents, diseases, weeds, and undesirable vegetation of many types. Pesticides are usually applied on a periodic basis, generally at intervals of several years. In most instances these pesticides are used only when they are cost-effective, and their benefits often outweigh environmental impacts.

The most important redistribution mechanism associated with pesticide pollution is direct transport by runoff. However, the mechanisms of leaching or subsurface flows may be important in areas of highly porous geologic materials, permeable soils, or high water tables.

Practices that control erosion and runoff also reduce loss of applied pesticides. In addition to these practices, a number of other often-used options exist. These options involve manipulation of the pesticide itself such as form, timing of application, etc.. These can be used alone or in conjunction with the erosion and runoff control measures. Table 3 lists the principal types of pesticide-management practices applicable to silvicultural activities and some of their favorable and unfavorable features.

Practices to control water pollution potentials from pesticide use include:

- Strict compliance with sound management of the chemicals whenever pesticides are used, even if runoff control measures are not necessary;
- Use of pesticides in strict accordance with the instructions on their labels;
- Storage of the chemicals to minimize the hazard of possible leakage;
- Prevention of direct application on water surfaces; and
- Disposal of containers after use in accordance with procedures approved under the provisions of the Federal Environmental Pesticide Control Act of 1972, as amended.

6. Control of Thermal Pollution

The most important factor influencing changes in water temperature, over which the forest manager has some control, is streamside shade.

TABLE 3

PRINCIPAL TYPES OF PESTICIDE PRACTICES APPLICABLE TO SILVICULTURAL ACTIVITIES AND SOME OF THEIR FAVORABLE AND UNFAVORABLE FEATURES IN TERMS OF WATER POLLUTION CONTROL

Pesticide Practice	Some Favorable and Unfavorable Features
Use of alternative control measures:	
biological controls	Very successful in a few test cases, can reduce insecticide and herbicide use appreciably. Further research and development needed before widespread applications are practical.
using insect and disease-resistant plant varieties	Can sometimes eliminate need for insecticide and fungicide. Additional research and development needed.
using mechanical control methods	Applicable to weed control and brush control along roads, will reduce need for chemicals substantially, not economically feasible for large areas. Increases possibility of sediment pollution. Requires adequate access.
Reducing excessive treatment	Reduces pesticide loss; refined predictive techniques required.
Managing aerial applications	Can reduce contamination of nontarget areas and direct application over streams and water bodies. Requires considerable skill in pesticide formulation, spray equipment, and aircraft capabilities.
Optimizing time of day for pesticide application	Universally applicable, can reduce necessary rates of pesticide application.
Removing and treating infected plants at a preselected location	Minimizes area affected by application. Usually applicable only when the problem is extremely localized. Requires adequate access. High costs.

In addition to shade provided by vegetation, water temperatures are also influenced by topography, surface area and volume of the stream, altitude, stream gradient, groundwater inflow, and type of stream or channel. However, by maintaining adequate vegetative cover of such height and density to adequately shade the stream during periods of maximum solar radiation, water temperature increases can often be prevented and/or minimized in order to meet management goals. Intentional reduction of shade, provided by vegetation, can also be used to increase water temperature to favor certain aquatic species, where desirable.

If vegetation is not spaced close enough, the stream may not be effectively shaded even though the vegetation is of sufficient height. In general, the most efficient shade producers are young, bushy, wide-crown trees. However, understory vegetation, including many species of brush (shrubs), generally provide very adequate shade for small streams.

The "state-of-the-art" has not advanced to the point where the amount, type, location, and width of vegetation that must be left to prevent and/or minimize increases in water temperature in any particular stream can be prescribed with certainty. This will vary from site to site depending upon the many factors previously described. Stream characteristics such as width, volume of flow, gradient, and stream bed collectively influence the effect on water temperatures of any given amount of exposure to solar radiation.

Although there has been significant progress in the development of techniques for predicting water temperature increases, these techniques have not been tested sufficiently for general application. Except for those areas where fully tested prediction techniques are available, local experience and professional judgement must be applied on a case-by-case basis.

Considerations for Specific Land Areas

For any given location, it is usually necessary to apply various combinations of practices or to modify specific practices due to specific site conditions, effectiveness of each of the various practices, overall management goals, or economic reasons.

Specific natural conditions that may be considered on a site-by-site basis are:

1. Physical and chemical characteristics of soils and geologic materials;
2. Landform and topography;
3. Intensity, duration, form, and frequency of precipitation;
4. Prevailing wind direction and velocity;
5. Current and anticipated runoff quantities, duration, timing, and velocities;
6. Occurrence and depth of groundwater;
7. Density, gradient, orientation, and characteristics of drainageways; and
8. [illegible] and character of [illegible] and plant [illegible].

Characteristics of these variable conditions, singularly and in combination, influence the mechanisms which control pollutant production and transport to receiving waters. These characteristics also influence potentials, hazards, limitations, and suitabilities of various silvicultural activities. The determination of Best Management Practices in each case must also consider the extent and scheduling of activities planned, the methods and kinds of equipment suitable for carrying out the activity, the time and duration of each activity, the time required for natural recovery of the area from any adverse impacts of the activity, such as soil compaction and

removal of vegetative cover from the ground surface; the specific ecological or silvicultural requirements of the plant species involved; the economic practicality and technical feasibility of management alternatives; and the other management objectives for the area.

Pollution potentials often differ widely within a relatively small geographic area. Therefore, control practices can be most accurately prescribed on a site-by-site basis. However, plans can be developed for a larger area if they allow flexibility in practice selection. Such BMP selection must correspond to detailed differences in soil types, slope characteristics, and other natural conditions.

There are a number of equations and formulas which can be used to assess the relative surface soil-erosion (sheet erosion) potential of an area, based upon an evaluation of the characteristics of factors such as rainfall, topography, soil, and vegetation. The potential effects of alternative management practices on water quality are generally reflected by changes in the factors which might be modified by the practices. These could include infiltration capacity of the soil, effective slope length, and amount of ground cover. Generalized predictive tools for determining sediment loadings from other sources of sediment, such as gullies, stream banks, and mass soil movement as well as loadings from other types of of pollutants, are described in EPA-660/2-76-151, May 1976, "Loading Functions For Assessment of Water Pollution From Nonpoint Sources." Due to the general nature of these estimating procedures, extreme care must be exercised in applying them to small, site-specific areas. In many parts of the Nation, local values have been developed through research and verified in connection with the use of these or similar predictive tools. Where available, these values usually provide more realistic estimates than those of the general equations or formulas.

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